The Urgent Need for Carbon Dioxide Sequestration

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There is a growing interest at Los Alamos National Laboratory to establish a center for CO_2 sequestration. Our work has afforded the Laboratory the opportunity to lead the nation in this field. This memo explains why the development of a viable sequestration technology is a long term strategic goal of utmost importance and why sequestration provides a goal worthy of the attention of the Laboratory.[1]

The danger of global warming has put in question the use of fossil fuels which constitute the most abundant and most reliable energy resource ever known to mankind. The need to reduce greenhouse gas emissions poses a serious threat to the world and US economy. Unfortunately, for reductions to have any effect they would have to be substantial. The US would have to reduce carbon dioxide emissions to less than 10% of the current level. The options for reducing greenhouse gas emissions, while at the same time providing for the growing energy demand of the world, are extremely limited. None of the competing energy resources, including nuclear, appear to be in a position to fill the gap should fossil energy consumption need to be substantially reduced. Therefore meeting the ever growing world demand for cheap energy, while simultaneously achieving the required drastic reduction in CO_2 emissions can only be accomplished by actively preventing carbon dioxide generated in the combustion of fuels from accumulating in the atmosphere, i.e. by sequestration.

Sequestration is possible, economically viable and currently the only realistic solution to the dilemma of CO_2 emissions. Existing technologies already demonstrate the feasibility of this approach. For example Statoil, a Norwegian natural gas producer, injects CO_2 that is co-produced at the gas well into a deep aquifer under the North Sea. Ocean disposal has been studied for years. Here in Los Alamos we have developed a very promising approach that disposes of carbon dioxide by chemically combining it in an exothermic reaction with readily available minerals to form carbonates. The resulting solid carbonates are stable on geological time scales and are known to be environmentally benign. This stands in contrast to most other methods that do not appear to fully solve the long term problem. Some, like ocean disposal, are fraught with their own environmental risks, others like deep aquifer disposal provide excellent regional solutions but in all likelihood will fall short of the scale required for unlimited access to fossil energy. Research into innovative methods of permanent carbon dioxide disposal and carbon dioxide reuse capable of dealing with the full scale of the problem is

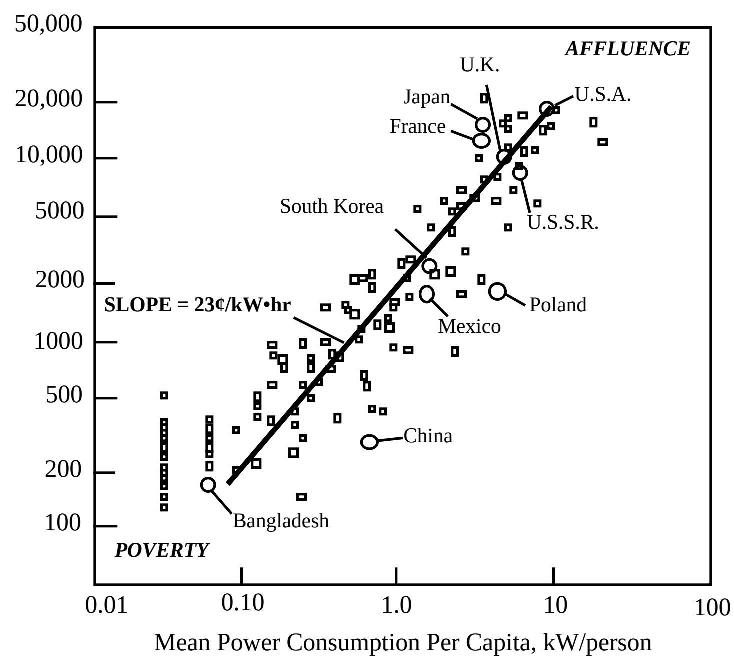

Figure 1. Per capita GDP versus per capita energy consumption for members of the United Nations. Taken from R. G. Watts, *Engineering Response to Global Climate Change*, Lewis Publishers, New York, 1997.

[1] For the sake of brevity we omit detailed references and only include a short bibliography of our technical work at the end of this memo. More detailed references can be found in these articles.

needed to solve the long term issues. New methods must be developed and must be shown to be cost-effective, safe, and environmentally acceptable. For fossil fuel to remain a viable energy option, CO_2 disposal must be permanent. If CO_2 reenters the atmosphere within a few centuries, the problem has only been postponed and not solved. Our research into the disposal as stable carbonate minerals and the recycling of CO_2 as an energy carrier aims at providing end-to-end sequestration methods that can operate on a scale that allows the unrestricted use of fossil energy for at least the coming millennium.

Sequestration is attractive, because any attempt at phasing out fossil energy is likely to fail due to the rapid growth in energy demand. As can be seen from Fig. 1, the wealth and productivity of a nation is directly related to its per capita energy consumption. Readily available, low-cost energy is an absolute necessity for the developing nations. Energy is required to achieve a decent standard of living and to overcome the political instability of a world sharply divided into rich and poor.

Figure 1 also points to the need of keeping energy costs low. The figure shows that the amount of gross domestic product (GDP) generated per kWh is only 23 cents. The cost of coal based electricity at 3 and 5 cents per kWh sets the scale. The margin for raising energy costs is small. An increase by 4 to 5 cents would strangle the economy. Wealth and an improved standard of living can only be achieved quickly and easily when the *difference* between the GDP and cost of energy going into the GDP is large. The price of energy must be kept low, especially in the developing countries where there is very little money available.

Fossil energy is in a unique position to satisfy the growing demand. Fossil energy is abundant and readily available, has high specific energy content, and most important, it is inexpensive. On the other hand the environmental impact of increased emissions of carbon dioxide from the consumption of fossil energy cannot be ignored.

The recent UN Summit in Kyoto resulted in important agreements limiting carbon dioxide emissions. The immediate consequences of the UN Framework Convention on Climate Change in Kyoto in 1997 may still be debated, but a long term picture is emerging from the gradual progress from Rio de Janeiro to Kyoto. There is a broad consensus that greenhouse gas emissions need to be controlled and that the level of carbon dioxide in the atmosphere cannot grow unchecked. Opinions vary as to what level of CO_2 would be tolerable from the claim that current levels (360 ppm) are already too high to the more relaxed attitude that a doubling of the pre-industrial carbon dioxide level to 550–600 ppm is acceptable. The political consensus that needs to be developed over the next few decades is likely to fall between these two scenarios.

It is indisputable that atmospheric CO_2 levels have risen from 280 ppm to 360 ppm due to human activities. Since 1958 levels have risen by nearly 50 ppm. Model calculations suggest that stabilization of the current CO_2 level of 360 ppm would require an overall reduction in worldwide emissions by about a factor of 3. For a level of 560 ppm (or twice the recent natural levels) to be sustainable, emissions must be held at about the world-wide 1990 level. These estimates are likely to be optimistic as they rely on poorly understood natural sinks for CO_2 which at present remove ~1/3 of industrial emissions. These sinks could very well become saturated with time.

Both of the above scenarios have serious implications for the US. Taking the less stringent requirement of holding the 1990 level of CO_2 emissions worldwide, we find the following. The US population of 250 million presently accounts for about 25% of the total world carbon dioxide emissions. For a future world population of 10 billion to share equally in a 1990 carbon dioxide emission level, it would be necessary for the US to reduce its per capita emissions to 10% of current levels. The more stringent requirement of stabilizing CO_2 atmospheric levels at current values, as opposed to keeping emissions at current levels would, as pointed out above, require an additional cut by a factor of three in US emissions. The reduction in CO_2 emission is further complicated by the likely growth in US energy demand. In the long term, a reduction by 90% or 97% in CO_2 emissions is almost equally traumatic. In the short term, the Kyoto treaty stipulates a reduction by 7% from 1990 levels which by the year 2010 would imply a reduction over business as usual of 30% to 40%.

The less ambitious goal of holding the atmosphere's CO_2 level below twice the natural level allows for a buffer of roughly 200 ppm in atmospheric CO_2. This buffer provides a chance to confront the problem in a systematic and orderly manner. At current emission rates, this buffer would last a long time (~150 years), but as overall emission rates grow the available time is cut short. Even with the Kyoto agreement in place, world CO_2 output will keep growing. Coal consumption in China grows annually by an amount equal to 15% of the US coal consumption. This increase alone dwarfs all the reductions the US agreed to in Kyoto between now and 2010. Thus even under the most relaxed scenario, it is unlikely that there will be much more than 50 years for the reudctions to take place. Fifty years is not a long time if one considers that power plants built today are likely to be still in service by the year 2050.

How can such a drastic reduction be accomplished? Energy efficiency and energy savings simply cannot come close to delivering a reduction by a factor of 10 to 30. Even a factor of two is questionable unless energy costs are raised dramatically. There is, however, no indication that fuel prices will have to rise in the next 50 years. The trend of the last two decades which proved the pessimists wrong suggests stable or falling costs for fossil energy. Resource estimates, particularly for coal, far exceed all anticipated demand and improvements in technology make the various fossil fuels virtually interchangeable. In the absence of cost increases, additional use for energy is likely to be found which would further increase demand. A likely example for increased energy consumption is the growing worldwide need for sea-water desalination.

Unless new technology drastically changes the balance in favor of other energy options, it is not likely that fossil energy is going to be phased out. Of course, it is possible that fusion, extremely cheap solar energy or some other unknown technology by virtue of being much cheaper will completely take over the energy market. There is, however, no indication that this will happen. Solar energy is still far too expensive. Wind, hydro- and geothermal energy are too limited in scope to fill in the gap. Nuclear energy is still more expensive than coal (by about 2 to 5 cents per kWh), and the political difficulties of large scale introduction of nuclear energy have proven hard to overcome. In addition, since most of the new power production capacity will go to developing nations, nuclear energy raises serious questions concerning nuclear proliferation. Given these limitations, it is evident that CO_2 sequestration is the only means of addressing the need for reduced CO_2 emission while maintaining a cheap and readily available fuel in the form of fossil energy. Success in this area will also greatly affect the political stability of the world in the next century.

By embracing a long term strategy that is strongly centered on CO_2 sequestration, the Laboratory can contribute to some of the most pressing issues facing the world.

Additional Reading

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